

## DESCRIPTION

## LUMINESCENT DEVICE

## 5 TECHNICAL FIELD

The present invention relates to a luminescent device using an organic compound, more particularly to a luminescent device exhibiting stability and high efficiency which is provided by using a metal coordination compound as a luminescent material.

## BACKGROUND ART

Organic EL devices as luminescent devices with high-speed response and high efficiency have been intensively investigated for their application (see Macromol. Symp. 125, 1-48 (1997), for example).

A copper coordination compound can be produced at a relatively low cost due to inexpensive raw materials, and low-cost and high performance organic EL devices can be obtained when performance of the copper coordination compound is fully utilized.

Organic EL devices using copper coordination compounds are disclosed in Japanese Patent No. 2940514 and Advanced materials 1999 11 No. 10 p. 852 Y. Ma et al. However, these EL devices have remarkably low luminescence efficiency, and these documents have insufficient description of device

efficiency. It is difficult to consider that the properties of the copper coordination compounds are fully exploited. Thus, these EL devices do not have enough performance to be used for displaying or  
5 lighting.

In addition, a luminescent material of a copper coordination compound used in Advanced materials 1999  
11 No. 10 p. 852 Y. Ma et al. has a molecular weight of 1,600 or more, and its molecular weight is so  
10 large that the material has inferior sublimation, thus making the material unsuitable for vacuum evaporation.

Further, copper coordination compounds having the same structure as some of the compounds used in  
15 the present invention are disclosed in Journal of chemical Society Dalton Transaction 1991 p. 2859; Journal of Chemical Society Dalton Transaction 1983 p. 1419; and Journal of Chemical Society Dalton Transaction 2001 p. 3069, but there is no description  
20 concerning luminescence therein.

In Journal of American Chemical Society, 2003  
125(40) p. 12072, there is a description of a trinuclear copper coordination compound different from the copper coordination compound of the present  
25 invention. The compound described therein has luminescence property, and application of the compound to an organic LED is suggested therein. The

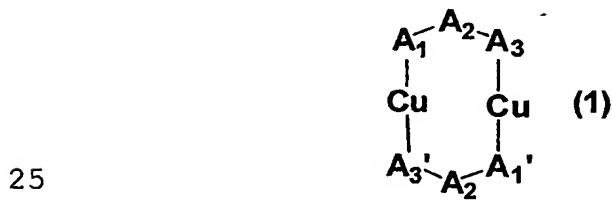
distance between copper atoms in the molecular of the compound is about 3.22 Å, and interaction between copper atoms is not strong. This trinuclear copper coordination compound can be vapor-deposited, but has 5 inferior luminescence property (efficiency) and stability for a device.

#### DISCLOSURE OF THE INVENTION

It is an object of the present invention to 10 provide a luminescent device using a luminescent material, which has high luminescence efficiency and high stability, and is available at a low cost.

Namely, a luminescent device of the present invention uses as a luminescent material a binuclear 15 copper coordination compound having a partial structure represented by the following general formula (1). Further, the above-described copper coordination compound preferably has a partial structure represented by the following general 20 formulae (2) and (3).

[Chemical Formula 1]

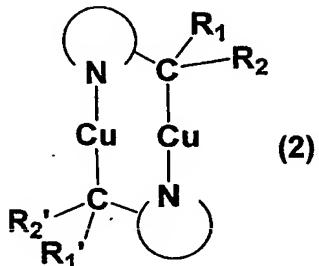


wherein Cu is a monovalent copper ion; and each of A<sub>1</sub>

to  $A_3$  and  $A_1'$ , to  $A_3'$ , is selected from the group consisting of a nitrogen atom, a carbon atom, and a phosphorus atom.

[Chemical Formula 2]

5



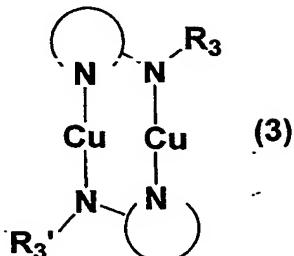
(2)

10

wherein each of  $R_1$ ,  $R_2$ ,  $R_1'$  and  $R_2'$  is a branched or straight alkyl group in which a hydrogen atom is optionally substituted by a halogen and which has 10 or less carbon atoms, an aromatic ring group 15 optionally having a substituent, a trimethylsilyl group, a dialkylamino group which is optionally substituted, or a diarylamino group; each of  $R_1$ ,  $R_2$ ,  $R_1'$  and  $R_2'$  may be the same or different; and  $N$  is an imine group on a heteroaromatic ring, and the 20 heteroaromatic ring is selected from the group consisting of a pyridine ring, a pyridazine ring, a pyrazine ring, a pyrimidine ring, a quinoline ring, an isoquinoline ring, a pyrazole ring, an azaquinoline ring, and an azaisoquinoline ring, and 25 these rings may have a substituent.

[Chemical Formula 3]

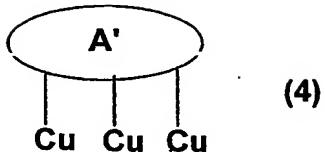
5



wherein each of  $R_3$  and  $R_3'$  is a branched or straight alkyl group in which a hydrogen atom is optionally substituted by a halogen and which has 10 or less carbon atoms, an aromatic ring group optionally having a substituent, and a trimethylsilyl group; each of  $R_3$  and  $R_3'$  may be the same or different; and N is an imine group in a heteroaromatic ring, and the heteroaromatic ring is selected from the group consisting of a pyridine ring, a pyridazine ring, a pyrazine ring, a pyrimidine ring, a quinoline ring, an isoquinoline ring, a pyrazole ring, an azaquinoline ring, and an azaisoquinoline ring, and these rings may have a substituent.

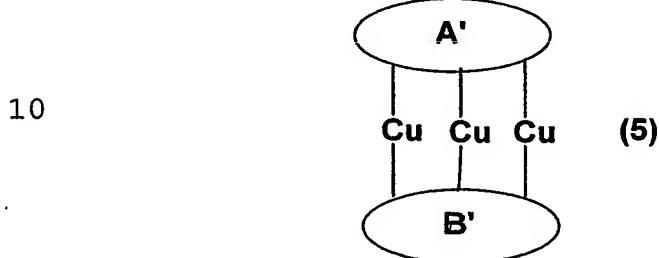
20 Another luminescent device of the present invention uses as a luminescent material a trinuclear copper coordination compound having a partial structure represented by the following general formula (4). Further, the copper coordination 25 compound preferably has a partial structure represented by the following general formula (5).

[Chemical Formula 4]



5 wherein Cu is a copper ion and A' is a tridentate ligand.

[Chemical Formula 5]



10 wherein B' is a tridentate ligand and may be the same  
15 as or different from A'.

In the above luminescent device of the present invention, the copper coordination compound preferably has a partial structure represented by the following general formula (6).

20 [Chemical Formula 6]



Further, it is preferable that the distance  
25 between copper atoms of the copper coordination compound is 3.2  $\text{\AA}$  or less.

Furthermore, it is preferable that the copper

of copper coordination compound is a monovalent ion.

Moreover, it is preferable that a luminescent layer contains a part of 100% of the copper coordination compound.

5

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A, 1B, 1C, 1D and 1E are cross sectional views showing one example of a luminescent device of the present invention;

10 Fig. 2 is a graph showing a luminescence spectrum of an exemplary compound 1001;

Fig. 3 is a graph showing a luminescence spectrum of a compound in a solid state in the present Example;

15 Fig. 4 is a graph showing a luminescence spectrum of a compound in a solid state in the present Example; and

Fig. 5 is a graph showing a luminescence spectrum of a compound in a solid state in the  
20 present Example.

#### BEST MODE FOR CARRYING OUT THE INVENTION

A copper coordination compound used in the present invention not only has high luminescence efficiency but also is suitable for vacuum deposition process or spin coating process wherein the compound is applied in a solution, or application method using

an ink jet nozzle, thereby enabling stable device fabrication with no damage such as decomposition in a device fabrication process. Therefore, the luminescent device of the present invention exhibits 5 high luminescence efficiency and high stability, and at the same time can be fabricated at a low cost.

Now, the present invention will be described in detail.

First, features of a copper coordination 10 compound are described which is a luminescent material of the present invention.

The copper coordination compound used in the present invention is a copper coordination compound having a partial structure represented by the above 15 general formulae (1) to (4), that is a binuclear copper coordination compound wherein two copper atoms are coupled to one or a plurality of bidentate ligands, or a trinuclear copper coordination compound wherein three copper atoms are coupled to one or a 20 plurality of tridentate ligands. The copper coordination compounds falling within this category exhibit thermal stability and high luminescence efficiency and are suitable for luminescent material. Particularly in a solid powder state, they are 25 characterized by stronger luminescence exhibited compared with other compounds.

In general, even among compounds that exhibit

strong luminescence in a dilute solution, many of them exhibit extremely weak luminescence in a solid powder state. These compounds form associations in the ground state by interaction between molecules of 5 the luminescent material or form exciplexes, this phenomenon is known as "concentration quenching" wherein original luminescence characteristic cannot be obtained.

It can be said that a Cu coordination compound 10 of the present invention is less susceptible to the concentration quenching. Therefore, when considering a luminescent layer in a luminescent device, the concentration quenching is generally prevented by adding a small amount of luminescent material as a 15 guest material to a host material. However, since the copper coordination compound of the present invention has no constraint of the concentration quenching, a high concentration of the compound can be applied or a luminescent layer of 100% of the 20 compound can be formed. As a result, luminescent devices which have high luminescence efficiency and good productivity can be fabricated. In addition, because of small concentration dependency of 25 luminescence characteristic, variations in fabrication can be reduced. In this view, luminescent devices with high productivity can be fabricated.

Here, it is preferable to use a copper ion of a center metal that is a monovalent cation.

Considering electron arrangement of a copper atom, a positive monovalent copper contains 10 d-electrons.

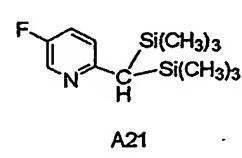
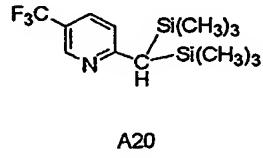
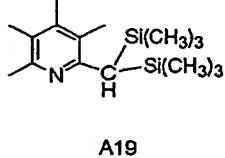
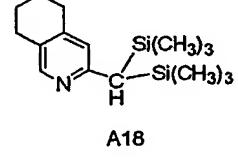
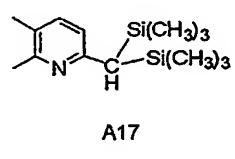
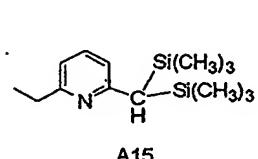
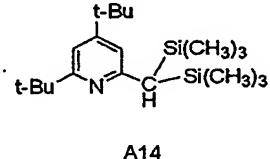
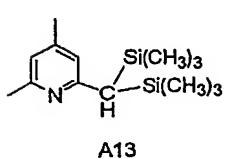
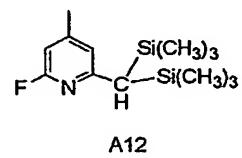
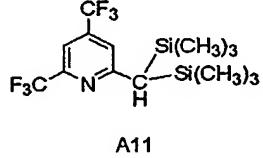
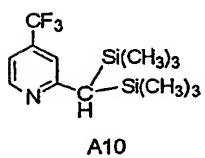
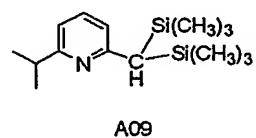
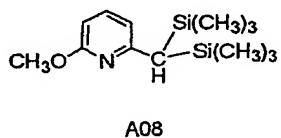
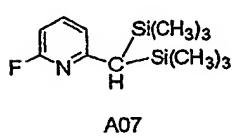
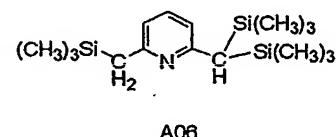
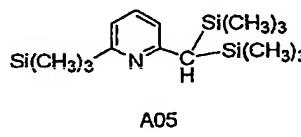
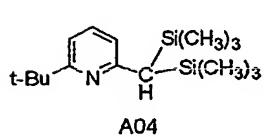
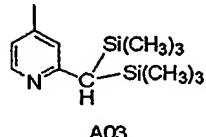
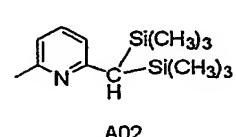
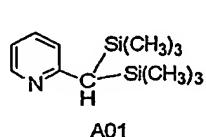
5 In general, there are many cases wherein a transition metal having even number of d electrons exhibits excellent luminescence characteristic.

In addition, vacuum deposition method is commonly employed for fabricating an organic LED 10 device in general since it enables the fabrication of a stable thin film with good quality. From our experiments, as the molecular weight of a compound becomes large, this deposition method cannot be employed. Accordingly, for vacuum deposition, the 15 copper coordination compound of the present invention has a molecular weight of preferably 1,500 or less, more preferably 1,200 or less.

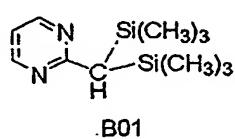
Chemical formulae of ligands that can be used for the present invention are shown below (it should 20 be noted that the following basic structures optionally have a condensed ring group or a substituent group. The substituent group is a halogen atom, a straight, branched or cyclic alkyl group or an aromatic ring group optionally having a 25 substituent.  $\text{CH}_2$  group of the alkyl group may be substituted with  $-\text{O}-$  or  $-\text{NR}-$  (R is an alkyl group or an aromatic ring group which may be substituted), and

a hydrogen atom of the alkyl group may be substituted with an aromatic ring group or a halogen atom.).

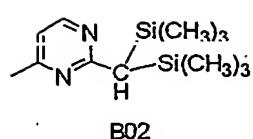
[Chemical Formula 8]



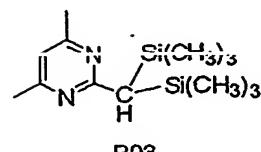
## [Chemical Formula 9]



B01



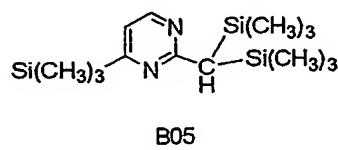
B02



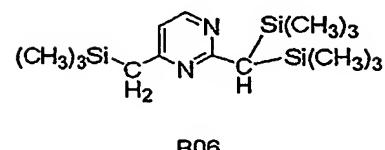
B03



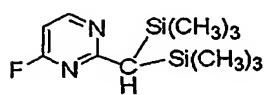
B04



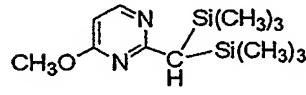
B05



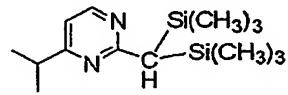
B06



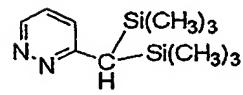
B07



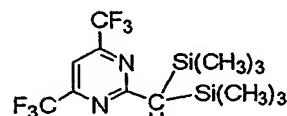
B08



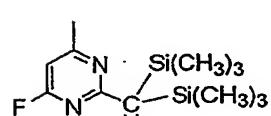
B09



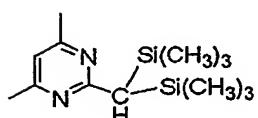
B10



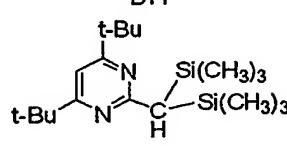
B11



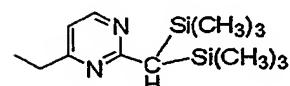
B12



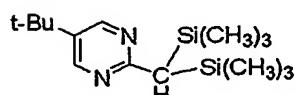
B13



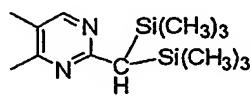
B14



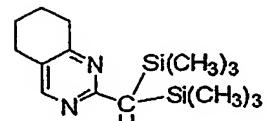
B15



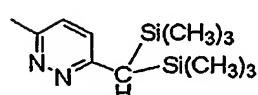
B16



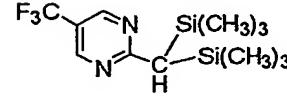
B17



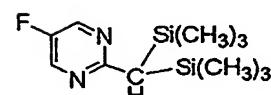
B18



B19

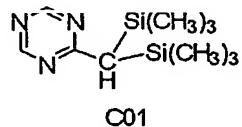


B20

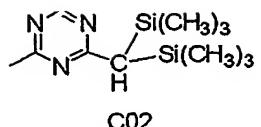


B21

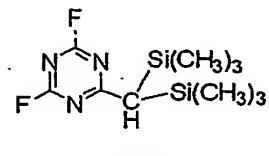
## [Chemical Formula 10]



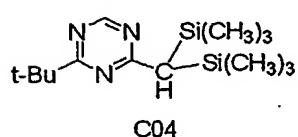
C01



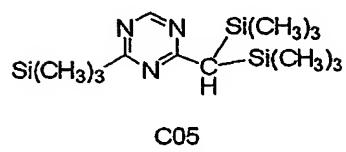
C02



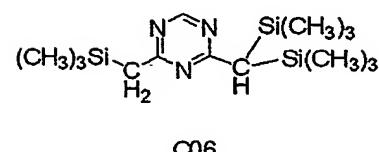
C03



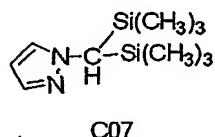
C04



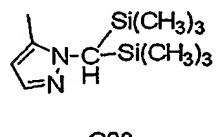
C05



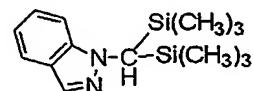
C06



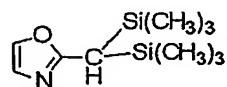
C07



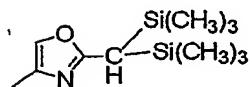
C08



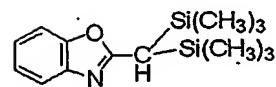
C09



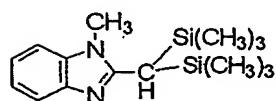
C10



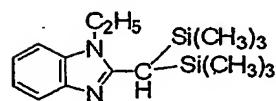
C11



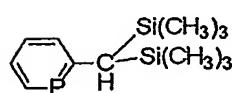
C12



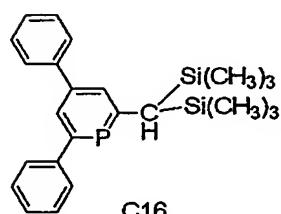
C13



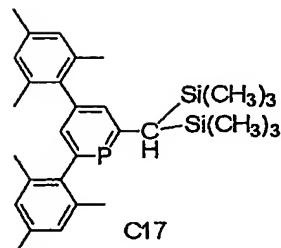
C14



C15

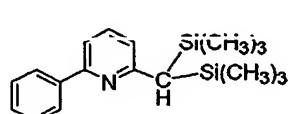


C16

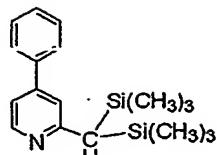


C17

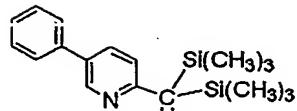
## [Chemical Formula 11]



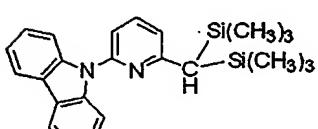
D01



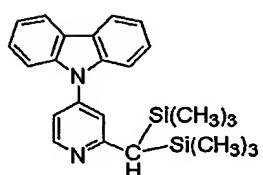
D02



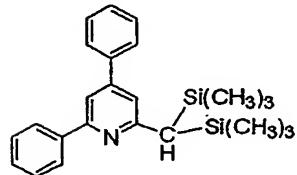
D03



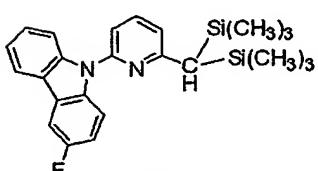
D04



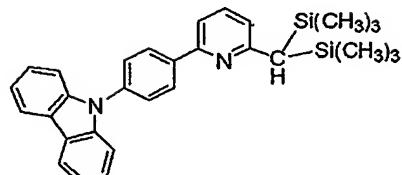
D05



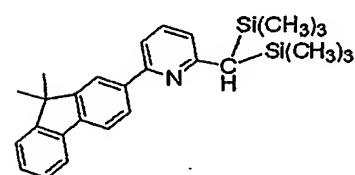
D06



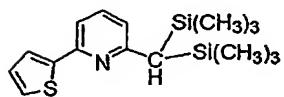
D07



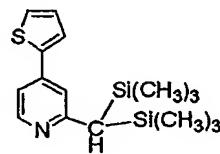
D08



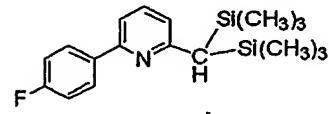
D09



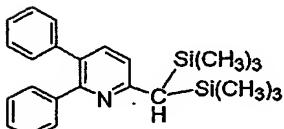
D10



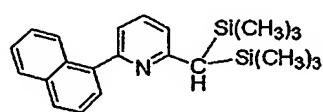
D11



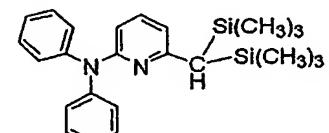
D12



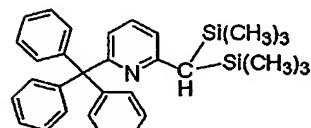
D13



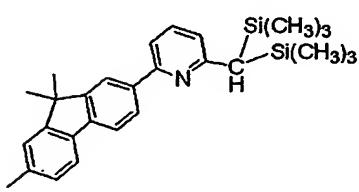
D14



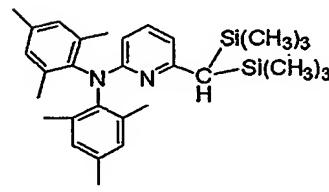
D15



D16

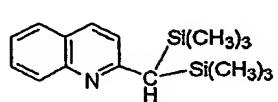


D17

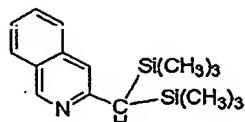


D18

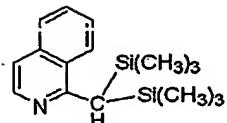
## [Chemical Formula 12]



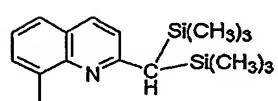
E01



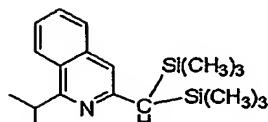
E02



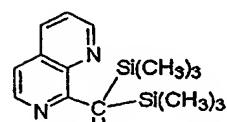
E03



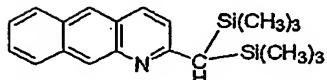
E04



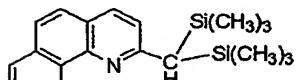
E05



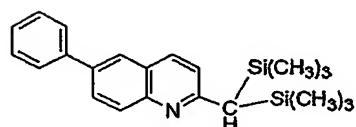
E06



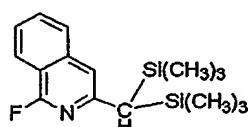
E07



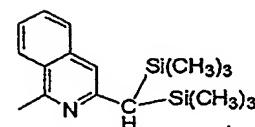
E08



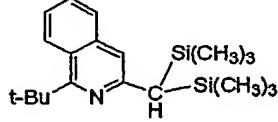
E09



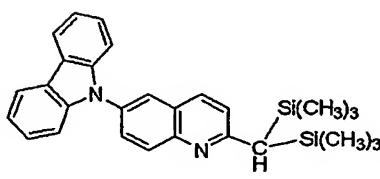
E11



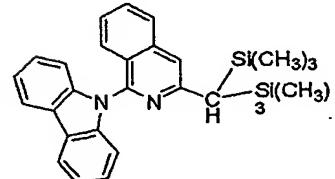
E12



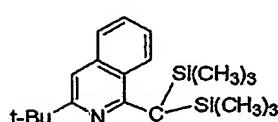
E13



E14

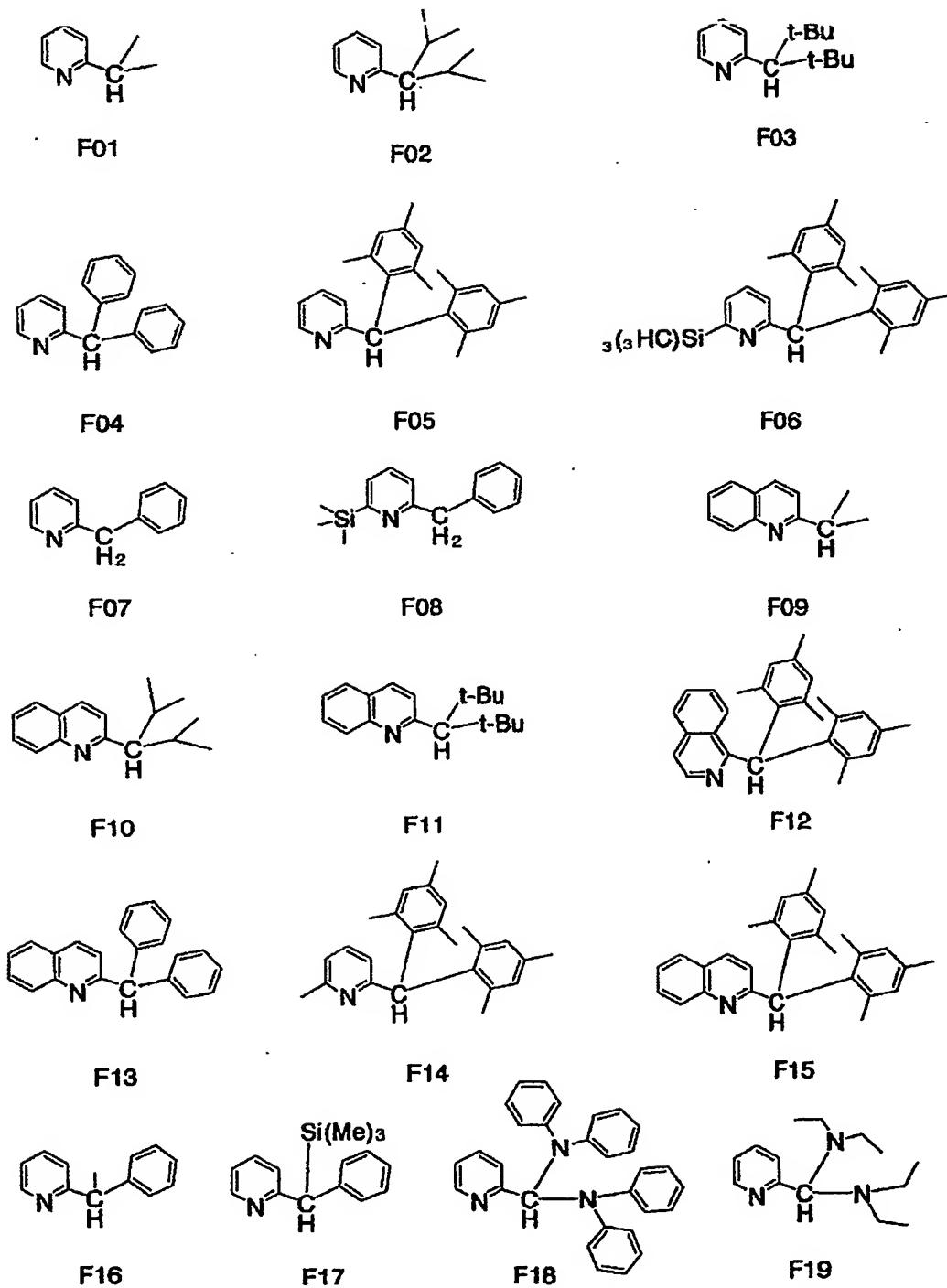


E15

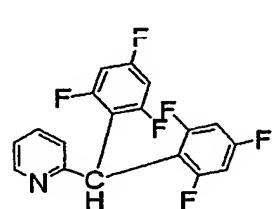


E16

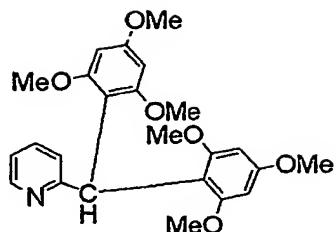
## [Chemical Formula 13]



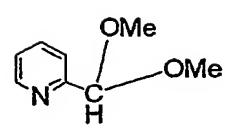
## [Chemical Formula 14]



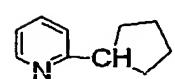
G01



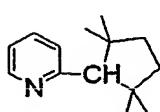
G02



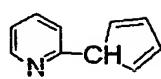
G03



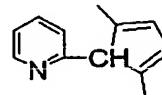
G04



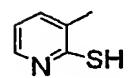
G05



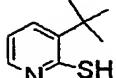
G06



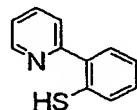
G07



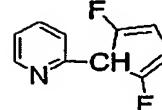
G08



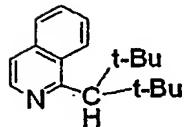
G09



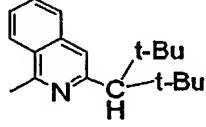
G10



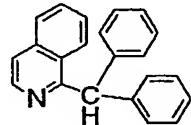
G11



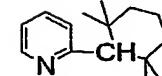
G12



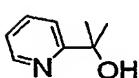
G13



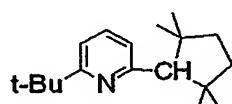
G14



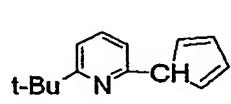
G15



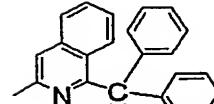
G16



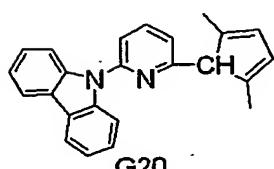
G17



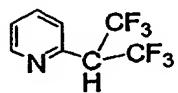
G18



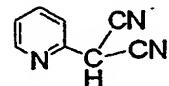
G19



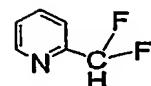
G20



G21

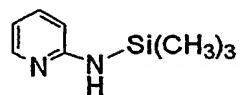


G22

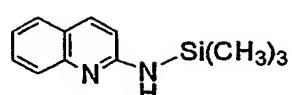


G23

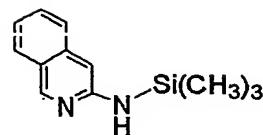
## [Chemical Formula 15]



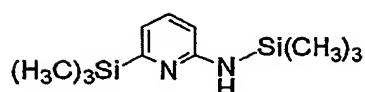
H01



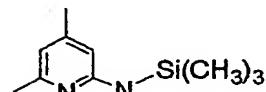
H02



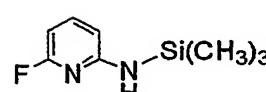
H03



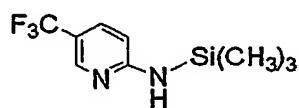
H04



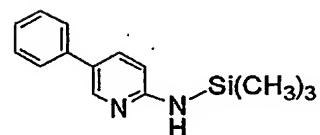
H05



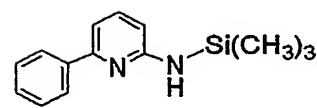
H06



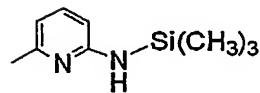
H07



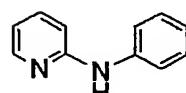
H08



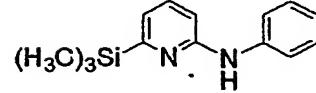
H09



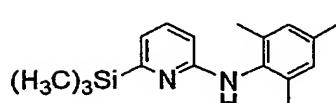
H10



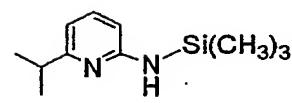
H11



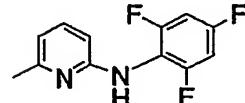
H12



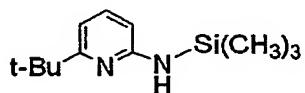
H13



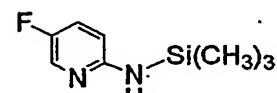
H14



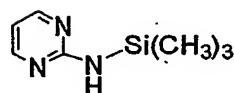
H15



H16

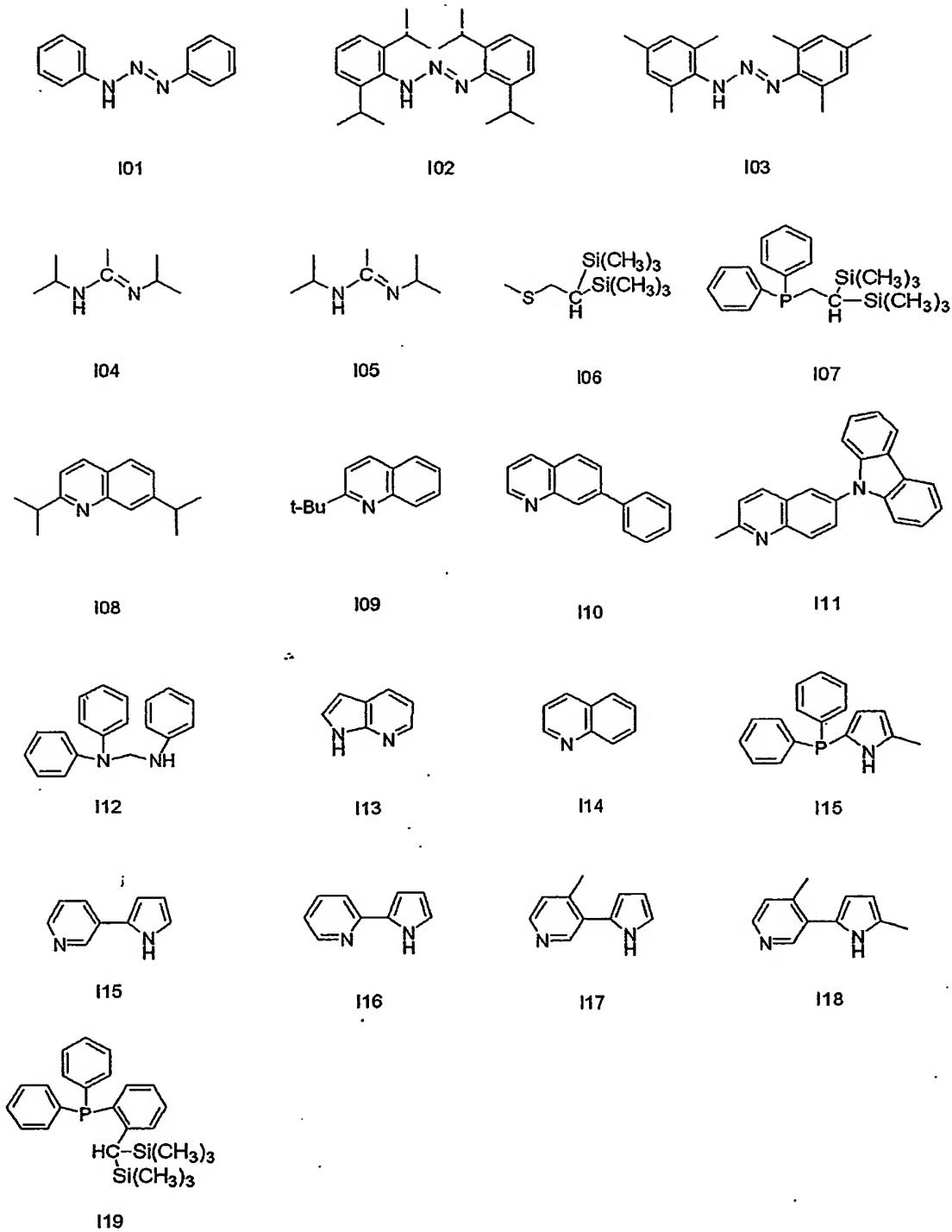


H17

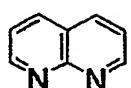


H18

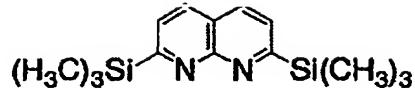
[Chemical Formula 16]



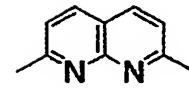
## [Chemical Formula 17]



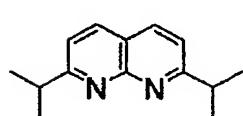
J01



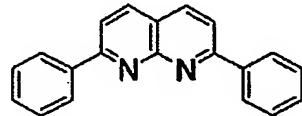
J02



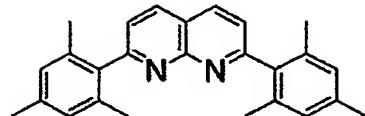
J03



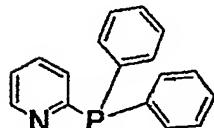
J04



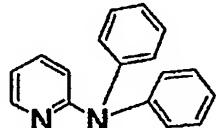
J05



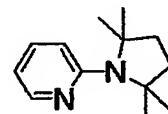
J06



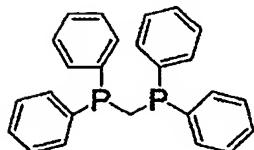
J07



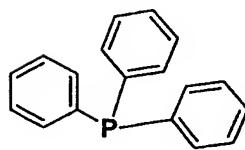
J08



J09



J10



J11

Ligands shown in chemical formulae 6 to 15 may become a bidentate ligand with negative monovalence after a hydrogen atom is withdrawn from "CH" or "NH" in the formulae, so that the hydrogen atom-withdrawn 5 nitrogen atom or carbon atom become a coordinating atom to a copper atom. Further, since ligands shown in chemical formula 16 are zerovalent, a coordination compound as a whole is positive divalent. In the case of these ionic coordination compounds,  $\text{PF}_6^-$ , 10  $\text{ClO}_4^-$ ,  $\text{BF}_4^-$  and a halogen ion can be used as a counter anion. For example, quadridentate ligands in which two of bidentate ligands shown in chemical formulae 6 to 16 are coupled by a covalent bond can be used as a ligand of the present invention.

15 Next, specific examples of the copper coordination compound of the present invention are shown in Tables 1 to 7 and Chemical Formula 17. Reference characters in the columns of "A and B", "A" and "B" of the Tables represent the above-described 20 ligands. Tables 1 and 2 show coordination compounds in which ligands A and B have the same structure. Tables 3 to 7 show coordination compounds in which ligands A and B have different structures. Chemical Formula 17 shows trinuclear coordination compounds.

Table 1

Compound Number	A and B
1001	A01
1002	A02
1003	A03
1004	A04
1005	A05
1006	A06
1007	A07
1008	A08
1009	A09
1010	A10
1011	A11
1012	A12
1013	A13
1014	A14
1015	A15
1016	A16
1017	A17
1018	A18
1019	A19
1020	A20
1021	A21
1022	B01
1023	B02
1024	B03
1025	B04
1026	B05
1027	B06
1028	B07
1029	B08
1030	B09
1031	B10
1032	B11
1033	B12
1034	B13
1035	B14
1036	B15
1037	B16
1038	B17
1039	B18
1040	B19
1041	B20
1042	B21
1043	C01
1044	C02
1045	C03
1046	C04
1047	C05
1048	C06
1049	C07
1050	C08

Compound Number	A and B
1051	C09
1052	C10
1053	C11
1054	C12
1055	C13
1056	C14
1057	C15
1058	C16
1059	C17
1060	D01
1061	D02
1062	D03
1063	D04
1064	D05
1065	D06
1066	D07
1067	D08
1068	D09
1069	D10
1070	D11
1071	D12
1072	D13
1073	D14
1074	D15
1075	D16
1076	D17
1077	D18
1078	E01
1079	E02
1080	E03
1081	E04
1082	E05
1083	E08
1084	E07
1085	E08
1086	E09
1087	E10
1088	E11
1089	E12
1090	E13
1091	E14
1092	E15
1093	E16
1094	F01
1095	F02
1096	F03
1097	F04
1098	F05
1099	F06
1100	F07

Compound Number	A and B
1101	F08
1102	F09
1103	F10
1104	F11
1105	F12
1106	F13
1107	F14
1108	F15
1109	F16
1110	F17
1111	G01
1112	G02
1113	G03
1114	G04
1115	G05
1116	G06
1117	G07
1118	G08
1119	G09
1120	G10
1121	G11
1122	G12
1123	G13
1124	G14
1125	G15
1126	G16
1127	G17
1128	G18
1129	G19
1130	G20
1131	G21
1132	G22
1133	G23
1134	H01
1135	H02
1136	H03
1137	H04
1138	H05
1139	H06
1140	H07
1141	H08
1142	H09
1143	H10
1144	H11
1145	H12
1146	H13
1147	H14
1148	H15
1149	H16
1150	H17

Table 2

Compound Number	A and B
1151	I1
1152	I2
1153	I3
1154	I4
1155	I5
1156	I6
1157	I7
1158	I8
1159	I9
1160	I10
1161	I11
1162	I12
1163	I13
1164	I14
1165	I15
1166	I16
1167	I17
1168	I18
1169	I19
1170	J01
1171	J02
1172	J03
1173	J04
1174	J05
1175	J06
1176	J07
1177	J08
1178	J09
1179	J10
1180	F18
1181	F19

Table 3

Compound Number	A	B
2001	A01	A02
2002	A01	A04
2003	A01	A05
2004	A01	A06
2005	A01	A07
2006	A01	A09
2007	A01	A11
2008	A01	A12
2009	A01	A13
2010	A01	A14
2011	A01	A15
2012	A01	A21
2013	A01	B01
2014	A01	B02
2015	A01	B06
2016	A01	B11
2017	A01	B12
2018	A01	B20
2019	A01	C01
2020	A01	C02
2021	A01	C04
2022	A01	C05
2023	A01	C06
2024	A01	C07
2025	A01	C10
2026	A01	C11
2027	A01	C12
2028	A01	C13
2029	A01	C14
2030	A01	C16
2031	A01	C07
2032	A01	D01
2033	A01	D04
2034	A01	D06
2035	A01	D07
2036	A01	D08
2037	A01	D09
2038	A01	D15
2039	A01	D16
2040	A01	D17
2041	A01	D18
2042	A01	E03
2043	A01	E08
2044	A01	E11
2045	A01	E12
2046	A01	E13
2047	A01	E14
2048	A01	E15
2049	A01	E16
2050	A01	F01

Compound Number	A	B
2051	A01	F03
2052	A01	F04
2053	A01	F05
2054	A01	F11
2055	A01	F14
2056	A01	F17
2057	A01	G01
2058	A01	G02
2059	A01	G03
2060	A01	G06
2061	A01	G12
2062	A01	G13
2063	A01	G15
2064	A01	G20
2065	A01	G21
2066	A01	G23
2067	A01	H01
2068	A01	H04
2069	A01	H10
2070	A01	H12
2071	A01	H14
2072	A01	H17
2073	A01	I01
2074	A01	I03
2075	A01	I14
2076	A01	I15
2077	A01	J01
2078	A01	J07
2079	A01	J10
2080	A02	A04
2081	A02	A05
2082	A02	A06
2083	A02	A07
2084	A02	A09
2085	A02	A11
2086	A02	A12
2087	A02	A13
2088	A02	A14
2089	A02	A15
2090	A02	A21
2091	A02	B01
2092	A02	B02
2093	A02	B10
2094	A02	B11
2095	A02	B12
2096	A02	B20
2097	A02	C01
2098	A02	C02
2099	A02	C04
2100	A02	C05

Compound Number	A	B
2101	A02	C06
2102	A02	C07
2103	A02	C10
2104	A02	C11
2105	A02	C12
2106	A02	C13
2107	A02	C14
2108	A02	C16
2109	A02	C07
2110	A02	D01
2111	A02	D04
2112	A02	D06
2113	A02	D07
2114	A02	D08
2115	A02	D09
2116	A02	D15
2117	A02	D16
2118	A02	D17
2119	A02	D18
2120	A02	E03
2121	A02	E08
2122	A02	E11
2123	A02	E12
2124	A02	E13
2125	A02	E14
2126	A02	E15
2127	A02	E16
2128	A02	F01
2129	A02	F03
2130	A02	F04
2131	A02	F05
2132	A02	F11
2133	A02	F14
2134	A02	F17
2135	A02	G01
2136	A02	G02
2137	A02	G03
2138	A02	G06
2139	A02	G12
2140	A02	G13
2141	A02	G15
2142	A02	G20
2143	A02	G21
2144	A02	G23
2145	A02	H01
2146	A02	H04
2147	A02	H10
2148	A02	H12
2149	A02	H14
2150	A02	H17

Table 4

Compound Number	A	B
2151	A02	I01
2152	A02	I03
2153	A02	I14
2154	A02	I15
2155	A02	J01
2156	A02	J07
2157	A02	J10
2158	A03	A09
2159	A03	A13
2160	A03	A18
2161	A03	A20
2162	A03	B01
2163	A03	B02
2164	A03	B10
2165	A03	B13
2166	A03	B19
2167	A03	C01
2168	A03	C06
2169	A03	C10
2170	A03	C14
2171	A03	C16
2172	A03	D04
2173	A03	D08
2174	A03	D09
2175	A03	D15
2176	A03	D16
2177	A03	D18
2178	A03	E02
2179	A03	E12
2180	A03	F03
2181	A03	F04
2182	A03	F14
2183	A03	F17
2184	A03	G01
2185	A03	G18
2186	A03	H01
2187	A03	H10
2188	A03	H14
2189	A03	I1
2190	A03	I15
2191	A03	J07
2192	A04	A05
2193	A04	A06
2194	A04	A07
2195	A04	A09
2196	A04	A11
2197	A04	A12
2198	A04	A13
2199	A04	A14
2200	A04	A15

Compound Number	A	B
2201	A04	A21
2202	A04	B01
2203	A04	B02
2204	A04	B10
2205	A04	B11
2206	A04	B12
2207	A04	B20
2208	A04	C01
2209	A04	C02
2210	A04	C04
2211	A04	C05
2212	A04	C06
2213	A04	C07
2214	A04	C10
2215	A04	C11
2216	A04	C12
2217	A04	C13
2218	A04	C14
2219	A04	C16
2220	A04	C07
2221	A04	D01
2222	A04	D04
2223	A04	D06
2224	A04	D07
2225	A04	D08
2226	A04	D09
2227	A04	D15
2228	A04	D16
2229	A04	D17
2230	A04	D18
2231	A04	E03
2232	A04	E08
2233	A04	E11
2234	A04	E12
2235	A04	E13
2236	A04	E14
2237	A04	E15
2238	A04	E16
2239	A04	F01
2240	A04	F03
2241	A04	F04
2242	A04	F05
2243	A04	F11
2244	A04	F14
2245	A04	F17
2246	A04	G01
2247	A04	G02
2248	A04	G03
2249	A04	G06
2250	A04	G12

Compound Number	A	B
2251	A04	G13
2252	A04	G15
2253	A04	G20
2254	A04	G21
2255	A04	G23
2256	A04	H01
2257	A04	H04
2258	A04	H10
2259	A04	H12
2260	A04	H14
2261	A04	H17
2262	A04	I01
2263	A04	I03
2264	A04	I14
2265	A04	I15
2266	A04	J01
2267	A04	J07
2268	A04	J10
2269	A05	A09
2270	A05	A13
2271	A05	A18
2272	A05	A20
2273	A05	B01
2274	A05	B02
2275	A05	B10
2276	A05	B13
2277	A05	B19
2278	A05	C01
2279	A05	C06
2280	A05	C10
2281	A05	C14
2282	A05	C16
2283	A05	D04
2284	A05	D08
2285	A05	D09
2286	A05	D15
2287	A05	D16
2288	A05	D18
2289	A05	E02
2290	A05	E12
2291	A05	F03
2292	A05	F04
2293	A05	F14
2294	A05	F17
2295	A05	G01
2296	A05	G18
2297	A05	H01
2298	A05	H10
2299	A05	H14
2300	A05	I1

Table 5

Compound Number	A	B	Compound Number	A	B	Compound Number	A	B
2301	A05	I15	2351	A08	A09	2401	A09	E08
2302	A05	J07	2352	A08	A12	2402	A09	E11
2303	A06	A09	2353	A08	B01	2403	A09	E12
2304	A06	A13	2354	A08	B05	2404	A09	E13
2305	A06	A18	2355	A08	B20	2405	A09	E14
2306	A06	A20	2356	A08	C14	2406	A09	E15
2307	A06	B01	2357	A08	C16	2407	A09	E16
2308	A06	B02	2358	A08	D04	2408	A09	F01
2309	A06	B10	2359	A08	D09	2409	A09	F03
2310	A06	B13	2360	A08	D15	2410	A09	F04
2311	A06	B19	2361	A08	E03	2411	A09	F05
2312	A06	C01	2362	A08	F04	2412	A09	F11
2313	A06	C06	2363	A08	G21	2413	A09	F14
2314	A06	C10	2364	A08	I15	2414	A09	F17
2315	A06	C14	2365	A09	A11	2415	A09	G01
2316	A06	C16	2366	A09	A12	2416	A09	G02
2317	A06	D04	2367	A09	A13	2417	A09	G03
2318	A06	D08	2368	A09	A14	2418	A09	G06
2319	A06	D09	2369	A09	A15	2419	A09	G12
2320	A06	D15	2370	A09	A21	2420	A09	G13
2321	A06	D16	2371	A09	B01	2421	A09	G15
2322	A06	D18	2372	A09	B02	2422	A09	G20
2323	A06	E02	2373	A09	B10	2423	A09	G21
2324	A06	E12	2374	A09	B11	2424	A09	G23
2325	A06	F03	2375	A09	B12	2425	A09	H01
2326	A06	F04	2376	A09	B20	2426	A09	H04
2327	A06	F14	2377	A09	C01	2427	A09	H10
2328	A06	F17	2378	A09	C02	2428	A09	H12
2329	A06	G01	2379	A09	C04	2429	A09	H14
2330	A06	G18	2380	A09	C05	2430	A09	H17
2331	A06	H01	2381	A09	C06	2431	A09	I01
2332	A06	H10	2382	A09	C07	2432	A09	I03
2333	A06	H14	2383	A09	C10	2433	A09	I14
2334	A06	I1	2384	A09	C11	2434	A09	I15
2335	A06	I15	2385	A09	C12	2435	A09	J01
2336	A06	J07	2386	A09	C13	2436	A09	J07
2337	A07	A09	2387	A09	C14	2437	A09	J10
2338	A07	A12	2388	A09	C16	2438	A13	B01
2339	A07	B01	2389	A09	C07	2439	A13	B05
2340	A07	B05	2390	A09	D01	2440	A13	B20
2341	A07	B20	2391	A09	D04	2441	A13	C14
2342	A07	C14	2392	A09	D06	2442	A13	C16
2343	A07	C16	2393	A09	D07	2443	A13	D04
2344	A07	D04	2394	A09	D08	2444	A13	D09
2345	A07	D09	2395	A09	D09	2445	A13	D15
2346	A07	D15	2396	A09	D15	2446	A13	E03
2347	A07	E01	2397	A09	D16	2447	A13	F04
2348	A07	F04	2398	A09	D17	2448	A13	G21
2349	A07	G21	2399	A09	D18	2449	A13	I15
2350	A07	I15	2400	A09	E03	2450	A13	J07

Table 6

Compound Number	A	B
2451	B01	B05
2452	B01	B09
2453	B01	C14
2454	B01	C16
2455	B01	D04
2456	B01	D09
2457	B01	D15
2458	B01	E03
2459	B01	F04
2460	B01	G21
2461	B01	I15
2462	B01	J07
2463	B06	B09
2464	B06	C14
2465	B06	C16
2466	B06	D04
2467	B06	D09
2468	B06	D15
2469	B06	E03
2470	B06	F04
2471	B06	G21
2472	B06	I15
2473	B06	J07
2474	B13	C14
2475	B13	C16
2476	B13	D04
2477	B13	D09
2478	B13	D15
2479	B13	E03
2480	B13	F04
2481	B13	G21
2482	B13	I15
2483	B13	J07
2484	C01	C02
2485	C01	C04
2486	C01	C16
2487	C01	D04
2488	C01	D09
2489	C01	D15
2490	C01	E03
2491	C01	F04
2492	C01	G21
2493	C07	C09
2494	C07	C16
2495	C07	D04
2496	C07	D09
2497	C07	D15
2498	C07	E03
2499	C07	F04
2500	C07	G21

Compound Number	A	B
2501	C14	C16
2502	C14	D04
2503	C14	D06
2504	C14	D09
2505	C14	D16
2506	C14	E03
2507	C14	F04
2508	C14	G21
2509	C16	C17
2510	C16	D04
2511	C16	D06
2512	C16	D09
2513	C16	D16
2514	C16	E03
2515	C16	F04
2516	C17	D01
2517	C17	D04
2518	C17	D15
2519	D04	D07
2520	D04	D09
2521	D04	D15
2522	D04	D16
2523	D04	E03
2524	D04	E11
2525	D04	E12
2526	D04	F03
2527	D04	F05
2528	D04	F14
2529	D04	F17
2530	D04	G07
2531	D04	G11
2532	D04	G21
2533	D04	H05
2534	D04	H17
2535	D04	I14
2536	D09	D07
2537	D09	D09
2538	D09	D15
2539	D09	D16
2540	D09	E03
2541	D09	E11
2542	D09	E12
2543	D09	F03
2544	D09	F05
2545	D09	F14
2546	D09	F17
2547	D09	G07
2548	D09	G11
2549	D09	G21
2550	D09	H05

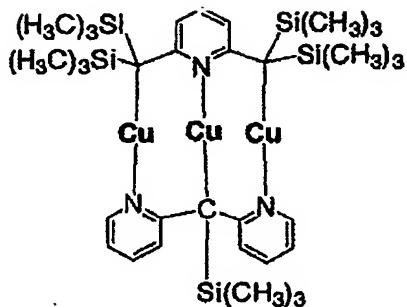
Compound Number	A	B
2551	D09	H17
2552	D09	I14
2553	D16	D16
2554	D16	E03
2555	D16	E11
2556	D16	E12
2557	D16	F03
2558	D16	F05
2559	D16	F14
2560	D16	F17
2561	D16	G07
2562	D16	G11
2563	D16	G21
2564	D16	H05
2565	D16	H17
2566	D16	J14
2567	E01	E03
2568	E01	A01
2569	E01	A02
2570	E01	A09
2571	E01	E11
2572	E01	E12
2573	E01	F03
2574	E01	F05
2575	E01	F14
2576	E01	F17
2577	E01	G07
2578	E01	G11
2579	E01	G21
2580	E01	H05
2581	E01	H17
2582	E01	I14
2583	E02	A01
2584	E02	A02
2585	E02	A09
2586	E03	E11
2587	E03	E12
2588	E03	F03
2589	E03	F05
2590	E03	F14
2591	E03	F17
2592	E03	G07
2593	E03	G11
2594	E03	G21
2595	E03	H05
2596	E03	H17
2597	E03	I14
2598	E05	A01
2599	E05	A02
2600	E05	A09

Table 7

Compound Number	A	B
2601	E12	F03
2602	E12	F05
2603	E12	F14
2604	E12	F17
2605	E12	G07
2606	E12	G11
2607	E12	G21
2608	E12	H05
2609	E12	H17
2610	E12	I14
2611	E15	E01
2612	E15	E02
2613	E15	E03
2614	E15	E08
2615	E15	F03
2616	E15	F05
2617	E15	F14
2618	E15	F17
2619	F03	F05
2620	F03	F14
2621	F03	F17
2622	F03	G07
2623	F03	G11
2624	F03	G21
2625	F03	H05
2626	F03	H17
2627	F03	I14
2628	F04	F05
2629	F04	F14
2630	F04	F17
2631	F04	G07
2632	F04	G11
2633	F04	G21
2634	F04	H05
2635	F04	H17
2636	F04	I14
2637	F05	A01
2638	F05	A02
2639	F05	A09
2640	F05	F14
2641	F05	F17
2642	F05	G07
2643	F05	G11
2644	F05	G21
2645	F17	G07
2646	G21	H12
2647	I08	I14
2648	I10	I14
2649	I10	I15
2650	I14	I15

Compound Number	A	B
2651	J01	J02
2652	J01	J03
2653	J01	J07
2654	J02	J07
2655	J03	J04
2656	J07	J08
2657	J07	J10

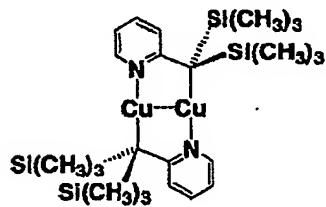
## [Chemical Formula 18]



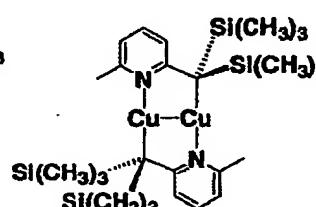
Exemplary compound 3001

5 Among the above examples, structural formulae of preferable copper coordination compounds are shown below.

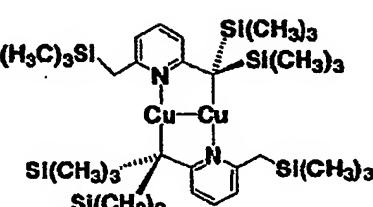
## [Chemical Formula 19]



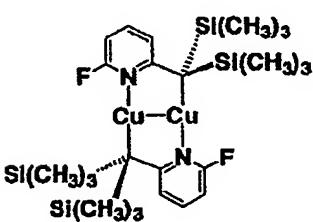
10  
Exemplary  
compound 1001



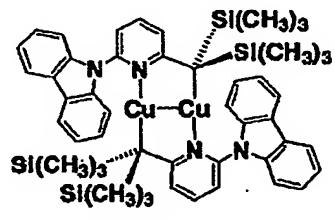
Exemplary  
compound 1002



Exemplary  
compound 1006



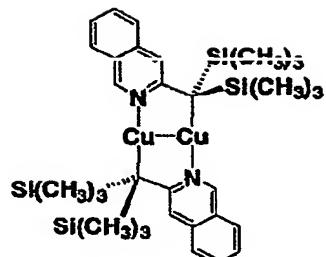
15  
Exemplary  
compound 1007



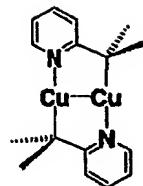
Exemplary  
compound 1063



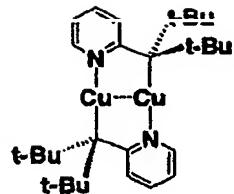
Exemplary  
compound 1078



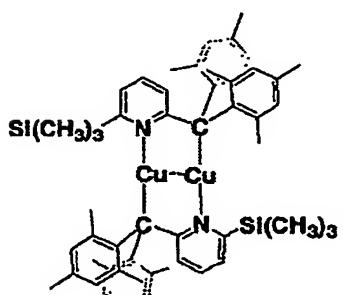
Exemplary  
compound 1079



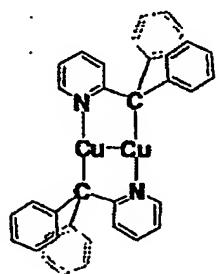
Exemplary  
compound 1094



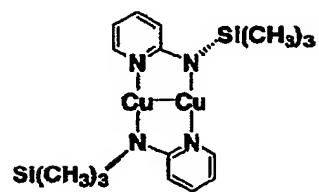
Exemplary  
compound 1096



Exemplary  
Compound 1099

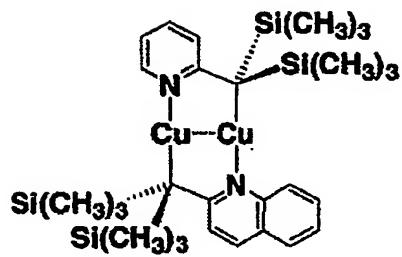


Exemplary  
compound 1097

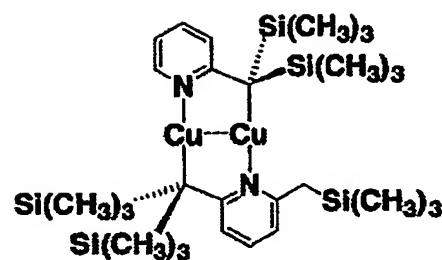


Exemplary  
compound 1134

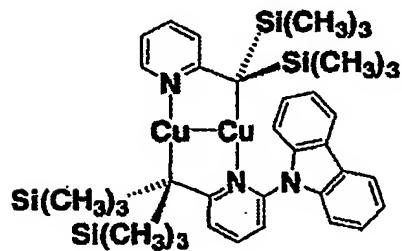
[Chemical Formula 20]



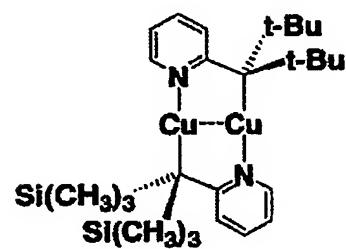
Exemplary compound 2568



Exemplary compound 2004



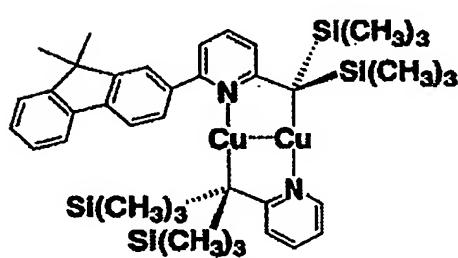
Exemplary compound 2033



Exemplary compound 2051

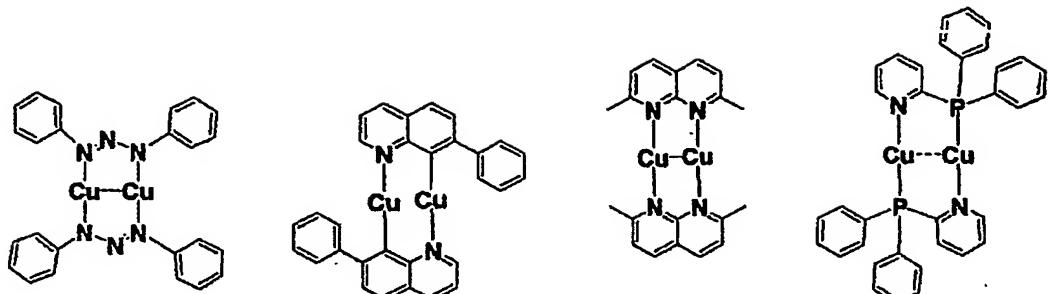


Exemplary compound 2347



Exemplary compound 2037

[Chemical Formula 21]



Exemplary

compound 1151

Exemplary

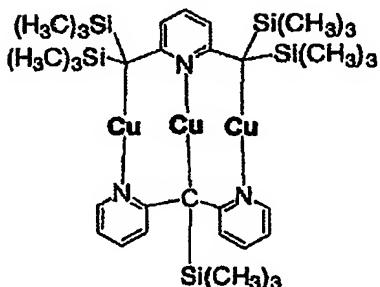
compound 1160

Exemplary

compound 1172

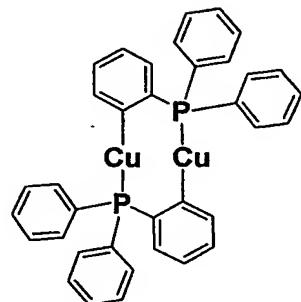
Exemplary

compound 1176



5

Exemplary compound 3001



Exemplary compound 3002

Many of these copper coordination compounds have a copper-copper interatomic distance of 3.2 Å or less, and interaction between copper atoms exists to maintain the bond therebetween. The copper coordination compound having a partial structure represented by the above general formula (1), preferably the above general formula (2) has two bidentate ligands such that the ligands surround two copper atoms from both ends of the two copper atoms.

Taking Exemplary compound 1001 as an example, two ligands A01 are used as this ligand, and a nitrogen atom in pyridine and a carbon atom adjacent to the pyridine ring are coordinating atoms. These ligands

5 are rotationally symmetrically coordinated in the coordination compound so as to surround two copper atoms. It is considered that an extremely bulky trimethylsilyl group in the ligand has an effect of stabilizing the bond between copper and ligand.

10 Since the ligand has a three-dimensionally bulky substituent group therein, thermal stability is improved and it is desired as a luminescent material. Exemplary compound 1001 has a copper interatomic distance of 2.41 Å in its molecule and has a strong

15 interaction. A compound having a copper interatomic distance of 3.2 or less Å has relatively strong interaction between copper atoms, thereby obtaining excellent thermal stability and luminescence characteristic.

20 A copper coordination compound using ligands having aromatic substituent group shown in Chemical Formula 10 can have not only a luminescence capability as a luminescent material but also a charge transport property due to its aromatic

25 substituent. For example, when these coordination compounds are used in a luminescent layer at a high concentration, charge transport becomes possible, so

that the use of the compound is more advantageous. Further, as the compound has several stable conformations, its amorphous property is enhanced to inhibit crystallization. This is more desirable for 5 improving the durability of an organic LED device. As another example, a structure having a trimethylsilyl group in one ligand but no trimethylsilyl group in the other ligand is possible like Exemplary compound 2051. This can destabilize a 10 structural symmetry, decrease crystallizability, and improve an amorphous property. Furthermore, like Exemplary compound 2054, a difference in conjugation length can be provided to localize an excited state, in addition to the presence or absence of a 15 trimethylsilyl group, thereby enhancing the stability of the device. The reason therefore is not clear, but it is possible to enhance the stability of the device by localizing an excited state of a luminescent material.

20 The luminescent material of the present invention exhibit good luminescence in a solid as mentioned above, and thus it can be used in a luminescent layer at a high concentration. However, when a coordination compound is constructed with the 25 same ligands, such compound is relatively easily crystallized. When this compound is used as a luminescent device, problems may arise such as easy

deterioration. Thus, crystallization can be inhibited by reducing the symmetry of its molecule. Examples of those compounds are shown in Tables 3 to 7. For example, Exemplary compound 2033 has a 5 carbazole group in one ligand but no carbazole group in the other ligand. A compound having such molecular structure has high amorphousness and low crystallizability, and therefore it is more desired as a luminescent material for an organic LED device.

10 The extremely strong luminescence characteristics of the copper coordination compounds of the present invention were observed for the first time by the present inventors, and its application to a luminescent device is disclosed. Accordingly, its 15 luminescence mechanism has not been revealed so far. The description at luminescence mentioned below provides one model for our luminescence mechanism.

As the lowest excited state in luminescence of the copper coordination compound of the present 20 invention, the following 3 types are considered, or a mixed state of these 3 types are considered.

- (1) MLCT (metal-to-ligand-charge-transfer) excited state
- (2) metal-centered excited state
- 25 (3) ligand-centered ( $\pi-\pi^*$ ) excited state

Since an excited state has a short life and is complicated, it is difficult to experimentally

identify in detail an excited state for each coordination compound.

As mentioned above, many copper coordination compounds of the present invention has a short 5 distance between copper atoms in its molecule and the distance is 3.2 Å or less. Twice the van der Waals' radius of copper atom is 2.8 Å, and it is considered that a new molecular orbital is formed due to interaction between copper atoms. The orbital formed 10 by this interaction between copper atoms has a higher energy than an occupied orbital of a single copper atom, and thus it can be a HOMO orbital (the highest occupied molecular orbital).

Further, many of the coordination compounds of 15 the present invention have an electron-deficiency heterocycle such as pyridine, pyrazine, pyrimidine, pyridazine, quinoline, isoquinoline, pyrazole, azaquinoline, and azaisoquinoline rings, directly coordinated with a copper atom through an N atom as 20 shown by, for example, the above general formula (3). When the compound is in an excited state, an electron is transited to an upper orbital from the ground state but the above heterocycle easily accepts the electron due to electron-deficiency. Thus, there are 25 many cases wherein the heterocycle accepts an electron from a copper atom at the time of excitation transition. A ligand having such heterocycle accepts

an electron from a copper atom at the time of excitation transition. When an electron is charge-transferred from a metal to a ligand at the time of excitation transition, such excited state is referred 5 to as MLCT excited state. The MLCT excited state of the Cu coordination compound of the present invention is considered as follows. That is, an orbital formed by interaction between two copper atoms becomes a HOMO orbital of the molecule, and charge transfer 10 from the HOMO orbital to a ligand occurs. This is the MLCT excited state.

Also, when the coordination compound among those of the present invention has no heterocycle in its molecule or accepts no electron at the time of 15 excitation transition, the excited state at the time of excitation transition becomes (2) metal-centered excited state. Also, it is considered that it becomes (3) ligand-centered ( $\pi-\pi^*$ ) excited state.

Luminescence is generally generated from the 20 lowest excited state. Since various excited states are "mixed" in the lowest excited state, the luminescence characteristic is determined depending upon which excited state is main in the lowest excited state.

25 With respect to MLCT excited state, when luminescence energy is changed by changing ligands, these ligands are determined to be in main excited

states. When the distance between copper atoms in the molecule is about 3.2 Å or less, a bonding orbital is formed due to metal interaction and thus such orbital is considered as MLCT transition.

5 Molecular structural characteristics such as a distance between copper atoms can be determined by X-ray crystal structure analysis.

The luminescence wavelength of the copper coordination compound of the present invention can be 10 controlled by changing a ligand. For example, the wavelength can be controlled by using an electron-withdrawing or electron-donating group on a pyridine ring, like a ligand shown in Chemical Formula 6. Further, the N atom number in a heterocycle or a ring 15 structure of a heterocycle can be changed as shown in Chemical Formulae 8 and 9. Furthermore, the luminescence wavelength can be controlled by changing the conjugation length of an aromatic ring as shown in Chemical Formulae 10 and 11.

20 The copper coordination compound of the present invention has a luminescent lifetime of 0.1 to 100 µs in a solid state. The luminescence occurs through a triplet excited state, and composed of delayed fluorescence or phosphorescence. The 25 photoluminescence yield is about 1 to 60%, and exhibits strong luminescence.

For high luminescence efficiency, it is

important to allow a compound to have a ligand structure so that structure changes between the ground state and an excited state are inhibited. The copper coordination compound of the present invention 5 inhibits the above structural changes more in a solid rather than in a solution, and thus strong luminescence can be obtained. This is one reason why the copper coordination compound exhibits good luminescence in a solid. Aluminum-quinolinol 10 derivatives, coumarin derivatives, quinacridon derivatives, which have been used so far, allow for extremely strong luminescence in a solution, and that strong luminescence characteristic is maintained in a solid state as it is. This characteristic 15 effectively works in the case of an organic EL device and high luminescence efficiency of the device can be obtained. However, the Cu coordination compound of the present invention exhibits stronger luminescence in a solid than in a solution. The present inventors 20 have noticed this characteristic and found that this characteristic is useful for highly efficient and stable luminescence of an organic EL device.

The Cu coordination compound of the present invention is useful as a luminescent material of an 25 organic EL device. The compound is suitable for vacuum-deposition process or spin coating process wherein the compound is applied in a solution, or

application method using an ink jet nozzle, in addition to high luminescence efficiency of the compound. With no damage such as decomposition in a device fabrication process, stable device fabrication 5 is possible.

Next, a luminescent device will be described. The luminescent device of the present invention preferably contains the above luminescent material in its luminescent layer.

10 Figs. 1A to 1E show basic structures of organic EL devices of the present invention. Reference numerals in the figures are explained as follows. Reference numeral 11 denotes a metal electrode, 12 a luminescent layer, 13 a hole-transporting layer, 14 a transparent electrode, 15 a transparent substrate, 16 an electron-transporting layer, and 17 an exciton diffusion prevention layer.

As shown in Figs. 1A to 1E, the organic EL device is generally composed of single or plural 20 organic layers which are sandwiched by the transparent electrode 14 on the transparent substrate 15 and the metal electrode 11.

Fig. 1A shows a simplest structure of the device wherein an organic layer is composed of only a 25 luminescent layer 12.

Figs. 1B and 1C show the devices having two organic layers, which are a luminescent layer 12 and

a hole-transporting layer 13; and a luminescent layer 12 and an electron-transporting layer 16, respectively.

Fig. 1D show the device having three organic 5 layers, which are a hole-transporting layer 13, a luminescent layer 12 and an electron-transporting layer 16.

Fig. 1E show the device having four organic 10 layers, which are a hole-transporting layer 13, a luminescent layer 12, an exciton diffusion prevention layer 17, and an electron-transporting layer 16.

For the luminescent layer 12, an aluminum-quinolinol complex or the like having electron 15 transport property and luminescence characteristic (typical example is Alq as shown below) is used.

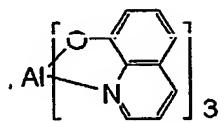
As the luminescent layer, it is possible to use a guest host type which contains a luminescent copper coordination compound of the present invention in a carrier-transporting material; only the luminescent 20 copper coordination compound at 100% concentration; or the layer composed of the luminescent copper coordination compound as a main component with the addition of a small amount of additive (e.g. carrier-transporting material or crystallization-preventing 25 material). Further, among guest host types, two carrier-transporting materials as guests, one having an electron-transporting property and the other

having a hole-transporting property, are used, and the luminescent copper coordination compound can be added thereto. Therefore, the luminescent layer of the present invention can be composed of a material 5 containing one or more components, considering performance improvement or productivity.

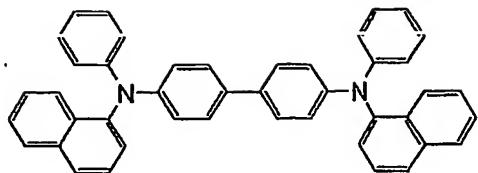
In addition, for the hole-transporting layer 13, triphenylamine derivatives (typical example is  $\alpha$ NPD), for example, are mainly used. In the case of 10 polymers, PVK is used. PVK has mainly hole-transporting property, and PVK itself exhibit blue EL luminescence.

As the electron-transporting layer 16, oxadiazole derivatives, for example, are used, or Alq, 15 Bphen or BCP as shown below can be used.

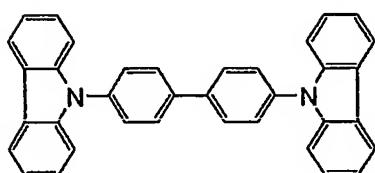
[Chemical Formula 22]



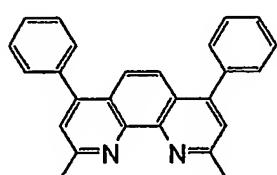
Alg.



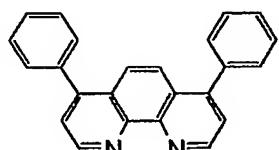
### $\alpha$ -NPD



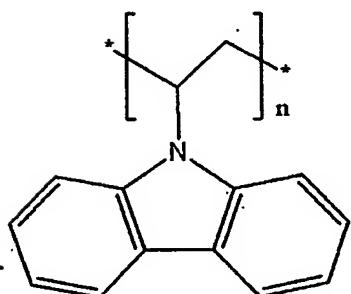
CBP



BCP

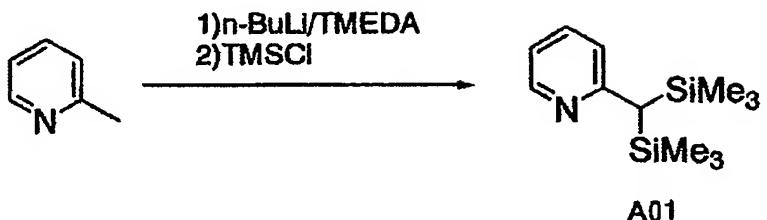


BPhen



PVK

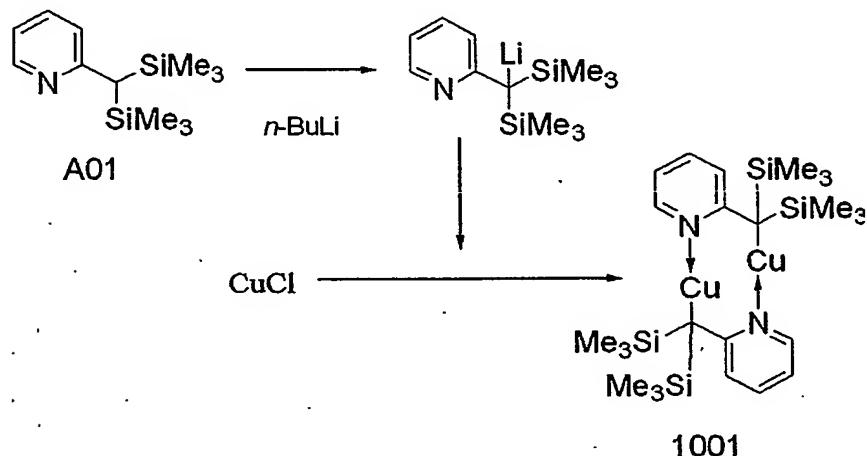
Production Example 1: production of Exemplary  
compound 1001  
[Chemical Formula 23]



5        Into a 1000-ml flask, 32.6 g of TMEDA (281 mmol) was charged with 150 ml of cyclohexane, and cooled to -30°C. To this solution, 345 ml of n-butyl lithium (2.4 M hexane solution) was dropwise added with a cannular, and 26.1 g (281 mmol) of 2-methyl pyridine was dropwise added to the resultant suspended solution with a dropping funnel. Thereafter, the reaction solution was heated and stirred at room temperature for 10 minutes. Then, the solution was again cooled down to -30°C, and 91.5 g (843 mmol) of trimethylsilyl chloride was dropwise added thereto with a dropping funnel. After stirring for 15 minutes, the resultant solution was heated to room temperature, and stirred for 2 hours. After the reaction, the resultant mixture was treated with water, and extraction was carried out with hexane (1L  $\times$  3). An organic layer thereof was washed with saturated saline and dried on magnesium sulfate. Then, the solvent thereof was evaporated and a crude

product was obtained. The obtained product was purified with column chromatography (ethyl acetate/hexane = 1/10), and distilled under reduced pressure to obtain 13.0 g of Compound A01 (yield 19%).

5 [Chemical Formula 24]



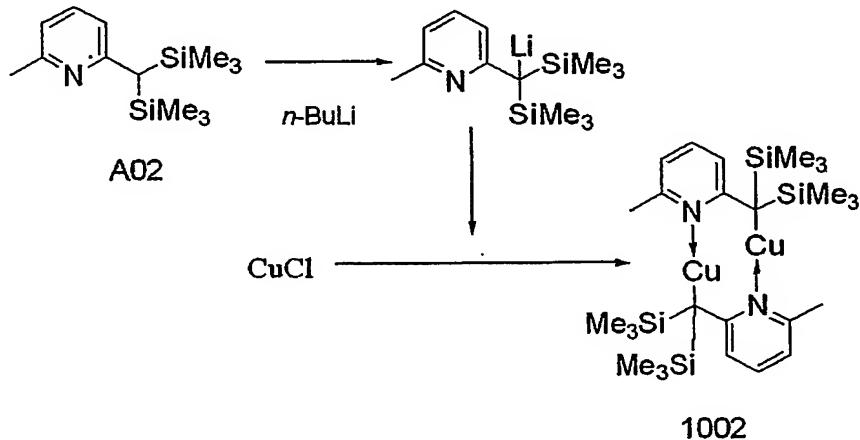
To a 100-ml two-necked flask, 952 mg of 2-(bis-trimethylsilyl-methyl)-pyridine (Compound A01) was charged with 20 ml of completely degassed dehydrated tetrahydrofuran, and 2.5 ml of n-butyllithium (4 mmol, 1.6 M hexane solution) was dropwise added while stirring at -20°C under nitrogen gas flow.

Thereafter, the resultant solution was heated gradually to room temperature. After the solution reached to room temperature, 496 mg (4 mmol) of copper chloride (I) was added thereto and the resultant mixture was stirred for 15 minutes. After the reaction was completed, the solvent thereof was evaporated in nitrogen atmosphere. 50 ml of

dehydrated and degassed hexane was added to the reaction mixture and the mixture was stirred. Then, in nitrogen atmosphere insoluble matters were filtrated. The resultant filtrate was concentrated 5 in nitrogen atmosphere, and the obtained solid product was purified by sublimation purification to obtain 350 mg (yield 29%) of Exemplary compound 1001.

Production Example 2: production of exemplary 10 compound 1002

[Chemical Formula 25]



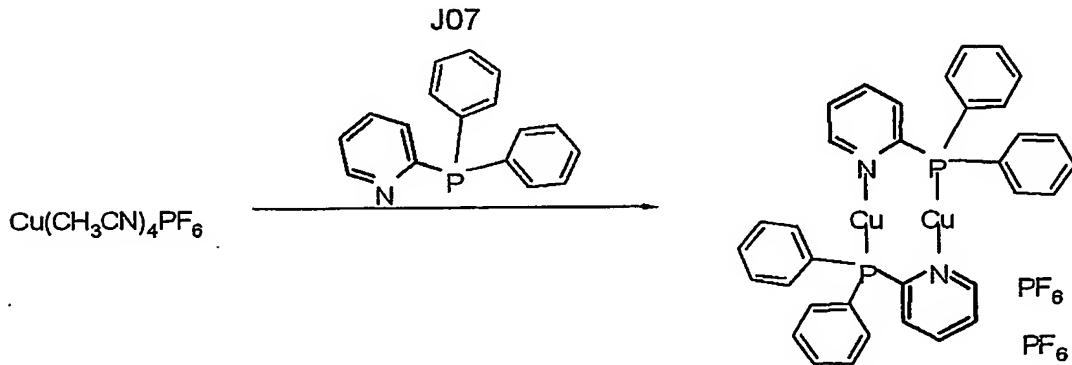
To a 100-ml two-necked flask, 1006 g (4 mmol) 15 of 2-(bis-trimethylsilyl-methyl)-6-methyl-pyridine (Compound A02) was charged with 20 ml of completely degassed and dehydrated tetrahydrofuran, and 2.5 ml of n-butyllithium (4 mmol, 1.6 M hexane solution) was dropwise added while stirring at -20°C under nitrogen 20 gas flow.

Thereafter, the resultant solution was heated gradually to room temperature. After the solution reached to room temperature, 496 mg (4 mmol) of copper chloride (I) was added thereto and the 5 resultant mixture was stirred for 15 minutes. After the reaction was completed, the solvent thereof was evaporated in nitrogen atmosphere. To the reaction mixture 50 ml of dehydrated and degassed hexane was added, and the mixture was stirred. Then, in 10 nitrogen atmosphere, insoluble matters were filtrated. The resultant filtrate was concentrated in nitrogen atmosphere, and the obtained solid product was purified by sublimation purification to obtain 390 mg (yield 31%) of Exemplary compound 1002.

15

Production example 3: production of Exemplary compound 1176

[Chemical Formula 26]



1176

To a 100-ml two-necked flask, 186 mg (0.5 mmol) of tetrakis(acetonitrile)copper(I)hexafluorophosphate and 20 ml of dehydrated toluene were fed and 132 mg (0.5 mmol) of 2-diphenylphosphanyl-pyridine (Compound 5 J07) was charged thereto under nitrogen gas flow.

Thereafter, the mixture was stirred for 1 hour.

After the reaction was completed, the solvent thereof was evaporated and recrystallization was carried out with chloroform/methanol to obtain 159 mg (yield 50%) of Exemplary compound 1176.

#### 10 Luminescence characteristics of compounds

Luminescence characteristics of compounds produced by Production Examples 1 to 3 were measured when these compounds were powder. Results thereof 15 are shown in Table 8. In addition, a luminescence spectrum of Exemplary compound 1001 is shown in Fig. 2 as a representative example.

Table 8

Exemplary Compound	Luminescence wavelength (nm)	Half-value width (nm)
1001	519	67
1002	525	70
1176	514	91

20

#### Examples 1 and 2

In these examples, a device having a device structure including three organic layers as shown in

Fig. 1D was used.

On a glass substrate (transparent substrate 15), 100 nm-thick ITO (transparent electrode 14) was patterned such that the resultant opposing electrodes 5 had an area of 3 mm<sup>2</sup>. The organic layers and the electrode layers described below were vacuum-deposited on the ITO substrate by resistive heating in a vacuum chamber at 10<sup>-4</sup> Pa for continuous deposition. Two kinds of luminescent layer 12 having 10 40 nm (Example 1) and 20 nm (Example 2) in thickness were prepared.

Hole-transporting layer 13 (thickness : 40 nm): compound FL1

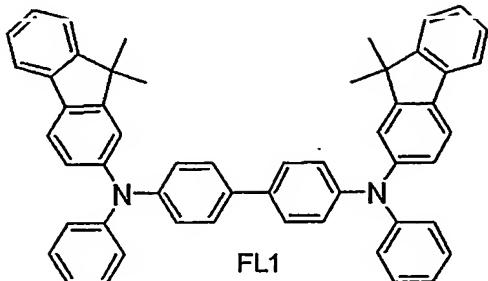
Luminescent layer 12 (thickness: 40 nm, 20 nm): 15 CBP/Exemplary compound 1001 (10% by weight based on CBP)

Electron-transporting layer 16 (thickness: 50 nm): BPhen

Metal electrode 1 (thickness: 1 nm): KF Metal 20 electrode 2 (thickness: 100 nm): Al

The structural formula of Compound FL1 is shown below.

[Chemical formula 27]



Example 3

In this Example, a device having the device  
5 structure including three organic layers shown in Fig.  
1D was used.

On an ITO substrate as prepared in the same  
manner as in Example 1, PEDOT (for organic EL)  
available from Bayer Corporation was applied by spin  
10 coating at 1000 rpm (20 sec.) to a thickness of 40 nm  
as a hole-transporting layer 13, and dried for 1 hour  
in a vacuum chamber at 120°C.

On top of that layer, the following solution  
was used for spin-coating at 2000 rpm for 20 seconds  
15 in nitrogen atmosphere so that the luminescent layer  
12 with a thickness of 50 nm was formed. The formed  
layer was dried in the same condition as in forming  
the hole-transporting layer 13.

Dehydrated chlorobenzene: 10 g  
20 Polyvinyl carbazole (average molecular weight 9600):  
92 mg

Exemplary compound 1001: 8 mg

This substrate was installed in a vacuum deposition chamber, and Bphen was vacuum-deposited thereon to form an electron-transporting layer 16 with a thickness of 40 nm.

5 Then, a cathode electrode (metal electrode 11) having the following structure was formed.

Metal electrode layer 1 (thickness: 15 nm) :

AlLi alloy (Li content: 1.8% by weight)

Metal electrode layer 2 (thickness: 100 nm) : Al

#### 10 Characteristics of devices

Characteristics of the device were evaluated by applying DC voltage to the metal electrode 11 as the negative side and the transparent electrode 14 as the positive side.

15 As for voltage-current characteristic, good rectification was exhibited. Luminescence spectrum and luminescence intensity were measured with spectrometers SR1 and BM7 manufactured by TOPCON Corporation. A current value at the time of voltage application was measured with 4140Bd manufactured by Hewlett-Pakard Corporation. Luminescence efficiency cd/A was calculated based on luminescence intensity and the measured current value. The results are 20 shown in Table 9.

Table 9

Example	Luminescence wavelength (nm)	300 cd		600 cd	
		cd/A	lm/w	cd/A	lm/W
1	535	20.7	10.1	18.1	9.2
2	535	24.9	17.8	21.4	14.5
3	540	11.5	5.2	10.1	4.3

The device exhibited excellent luminescence at 300 and 600 cd/cm<sup>2</sup>.

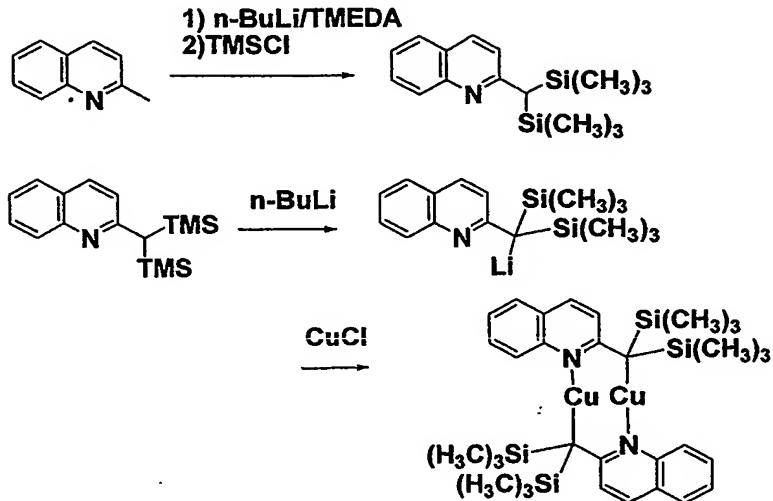
5 In Example 1, the external quantum efficiency was 7.5% and highly efficient luminescent device was obtained taking advantage of luminescence through a triplet excited state. Further, the devices of Examples 1 and 2 were energized for 100 hours for 10 luminescence. It was confirmed that stable luminescence was obtained at that time.

#### Example 4

Using the same synthesis method as shown in Production Example 1, Exemplary compound 1078 was 15 synthesized based on the following synthesis scheme. After the reaction between a ligand and CuCl, sublimation purification was carried out to obtain a compound in a synthesis yield of 10%. To identify the compound, elemental analysis and X-ray crystal 20 analysis were employed. Fig. 3 shows a luminescence spectrum of the compound of this example in a solid state. A strong orange luminescence was observed from the compound, which had a peak wavelength at 577

nm and a half-value width of 91 nm.

[Chemical Formula 28]



#### Example 5

Exemplary compound 1007 was synthesized based  
15 on the following synthesis scheme.

To a 300-ml reaction vessel, diisopropylamine  
(14 ml, 99 mmol) and diethylether (100 ml) were fed  
and cooled down to -40°C. To this mixture solution,  
n-butyllithium in 2.44 M hexane solution (41 ml, 99  
20 mmol) was added dropwise. The mixture solution was  
warmed to 0°C while stirring, and then cooled down to  
-78°C. Then, 2-fluoro-6-methyl pyridine (5.0 g, 45  
mmol) was added thereto. After stirring for 15  
minutes, trimethylsilyl chloride (12.6 ml, 99 mmol)  
25 was slowly added dropwise. Thereafter, the resultant  
solution was warmed and stirred at room temperature  
for 18 hours. To this mixture solution, water and

further hexane (150 ml) were added, and the mixture was separated to an organic layer and an aqueous layer. Then, the aqueous layer was extracted with hexane for collecting the organic layer. The 5 collected organic layer was washed with saturated saline and dried on  $MgSO_4$ . This solution was concentrated to obtain a light brown liquid of ligand.

The synthesis method for obtaining a copper coordination compound is the same as in Production 10 Example 1 of reaction between a ligand and  $CuCl$ . The reaction between the ligand and  $CuCl$  is followed by sublimation purification to obtain the compound in a synthesis yield of 20%. To identify the compound, elemental analysis and X-ray crystal analysis were 15 employed.

[Chemical Formula 29]

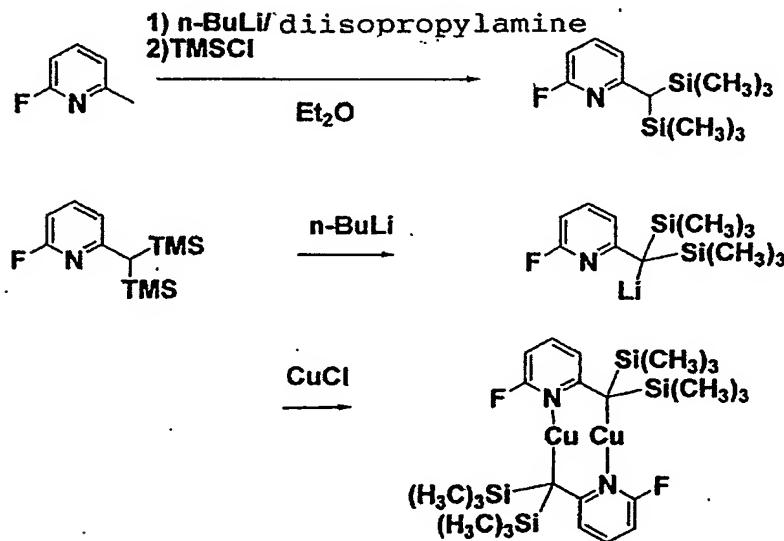


Fig. 4 shows a luminescence spectrum of the compound of this example in a solid state. A strong green luminescence was observed from the compound, which had a peak wavelength at 504 nm and a half-  
5 value width of 55 nm.

#### Example 6

Exemplary compound 3002 as the metal coordination compound was synthesized based on the following synthesis scheme. A ligand was obtained by  
10 reaction between trimethylsilyl diphenylphosphine and 1-iodine-2-bromobenzene in the presence of palladium catalyst in a benzene solvent. The method for obtaining a copper coordination compound was the same as in Production Example 1 of reaction between a  
15 ligand and CuCl. The reaction between the ligand and CuCl was carried out to obtain the compound in a synthesis yield of 12%. To identify the compound, elemental analysis and X-ray crystal analysis were employed.

[Chemical Formula 29]

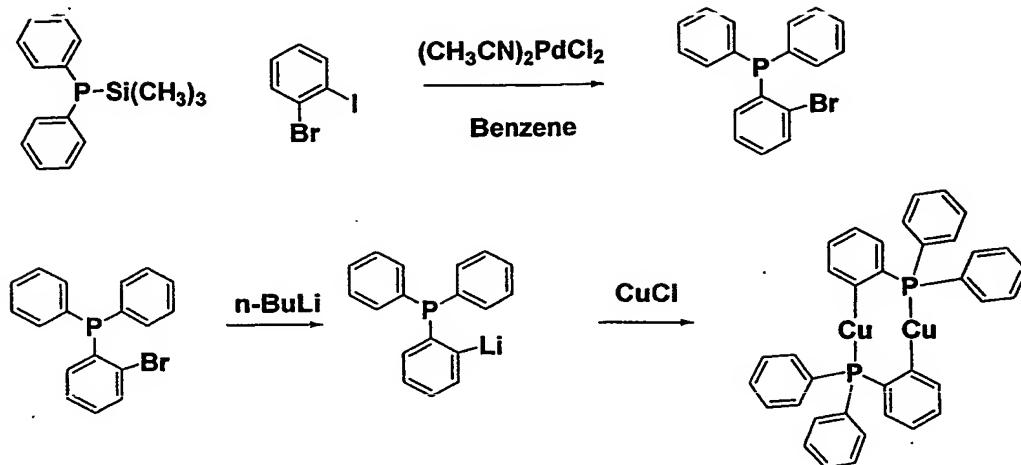


Fig. 5 shows a luminescence spectrum of the compound of this example in a solid state. A red luminescence was observed from the compound, which had a peak wavelength of 705 nm.

#### Examples 7 and 8

In Examples 7 and 8, the device having the same device structure as in Example 2 was produced except for a luminescent layer. These examples employed the same Exemplary compound 1001 as a luminescent dopant as in Example 2, but the concentration thereof was changed so that the device of Example 7 had a luminescent layer with 50% concentration of the Exemplary compound 1001 and 50% concentration of CBP and the device of Example 8 had a luminescent layer with 100% concentration of the Exemplary compound 1001. The thickness of the luminescent layer was 20

nm.

After the production of the devices, characteristics of the devices were evaluated. The results thereof are shown in the following table, 5 which shows the efficiency at 600 cd/m<sup>2</sup> of luminance.

Table 10

	Luminescence wavelength (nm)	cd/A	1m/W
Example 7	540	19.3	13.2
Example 8	550	19.0	12.0

As shown above, these Examples exhibited an 10 efficiency comparable with Example 2 wherein the concentration of the Exemplary compound 1001 in the luminescent layer was 10%. Thus, it is understood that Exemplary compound 1001 is a luminescent material that prevents concentration quenching, that 15 is no decrease of efficiency, even when the concentration thereof is high. Further, stable luminescence was exhibited even when continuous luminescence was performed at 300 cd/m<sup>2</sup>.

Examples 9, 10 and 11

20 In Examples 9 to 11, the devices having the same structure as in Examples 1 and 2 except that Exemplary compound 1007 was used as a luminescent dopant. In the luminescent layer, the Exemplary compound 1007 had a concentration of 10% by weight,

and the thicknesses of the luminescent layer were 40 nm (Example 9) and 20 nm (Example 10). Further, the luminescent layer of Example 11 had a thickness of 20 nm and was composed of only Exemplary compound 1007 5 without CBP.

Table 11

	Luminescence wavelength (nm)	cd/A	lm/W
Example 9	505	10.2	6.8
Example 10	505	15.0	11.0
Example 11	515	12.0	8.2

As shown above, the device using the Exemplary 10 compound 1007 exhibited high luminescence efficiency. It is understood that the Exemplary compound 1007 is an excellent luminescent dopant. Further, the device of Example 11 having the luminescent layer of 100% Exemplary compound 1007 exhibited good efficiency. 15 It is thus understood that the Exemplary compound 1007 is a luminescent material that prevents concentration quenching. Stable luminescence was exhibited even when continuous luminescence was performed at 300 cd/m<sup>2</sup>.

## 20 Example 12

In Example 12, the device having the same device structure as in Example 3, except that Exemplary compound 1176 synthesized in Production

Example 3 was used instead of Exemplary compound 1001.

Table 12

	Luminescence wavelength (nm)	cd/A	lm/W
Example 12	520	4.3	2.0

5        High luminescence efficiency was confirmed and also stable luminescence was exhibited even when continuous luminescence was performed at 300 cd/m<sup>2</sup>.

10        This application claims priority from Japanese Patent Application Nos. 2003-401821 filed on December 1, 2003 and 2004-298501 filed on October 13, 2004, which are hereby incorporated by reference herein.